ICARUS

International Journal of Solar System Studies

Published in Affiliation with the
Division for Planetary Sciences
American Astronomical Society

Editor
Joseph A. Burns
Cornell University
Ithaca, New York

Volume 94, 1991

ACADEMIC PRESS, INC.
Harcourt Brace Jovanovich, Publishers
San Diego New York Boston London Sydney Tokyo Toronto

Copyright © 1991 by Academic Press, Inc.
All Rights Reserved

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the copyright owner.

The appearance of the code at the bottom of the first page of an article in this journal indicates the copyright owner's consent that copies of the article may be made for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition, however, that the copier pay the stated per copy fee through the Copyright Clearance Center, Inc. (27 Congress Street, Salem, Massachusetts 01970), for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale. Copy fees for pre-1991 articles are as shown on the article title pages; if no fee code appears on the title page, the copy fee is the same as for current articles.

0019-1035/91 $3.00

MADE IN THE UNITED STATES OF AMERICA

This journal is printed on acid-free paper.

Contents of Volume 94

Number 1, November 1991

1 **CO_2 Condensation and the Climate of Early Mars**
James F. Kasting

14 **Mars Volatile Evolution: Evidence from Stable Isotopes**
Bruce M. Jakosky

32 **Infrared Solar Occultation Sounding of the Martian Atmosphere by the Phobos Spacecraft**
V. A. Krasnopolsky, O. I. Korablev, V. I. Moroz, A. A. Krysko, J. E. Blamont, and E. Chassefiere

45 **Absolute Wind Velocities in the Lower Thermosphere of Venus Using Infrared Heterodyne Spectroscopy**
Jeffrey J. Goldstein, Michael J. Mumma, Theodor Kostiuk, Drake Deming, Fred Espenak, and David Zipoy

64 **Equatorial Waves in the Stratosphere of Uranus**
David P. Hinson and Julio A. Magalhães

92 **A Disturbance in Jupiter's High-Speed North Temperate Jet during 1990**
A. Sanchez-Lavega, I. Miyazaki, D. Parker, P. Laques, and J. Lecacheux

98 **Planetary Accretion Rates: Analytical Derivation**
Richard Greenberg, William F. Bottke, Andrea Carusi, and G. B. Valsecchi

112 **On the Origin of the Planetary Spin by Accretion of Planetesimals. II. Collisional Orbits at the Hill Surface**
K. Tanikawa, N. Kikuchi, and I. Sato

126 **The Origin of the Systematic Component of Planetary Rotation. I. Planet on a Circular Orbit**
Jack J. Lissauer and David M. Kary

160 **Resonant Obliquity of Mars?**
William R. Ward and Donald J. Rudy

165 **Streamline Formalism and Ring Orbit Determination**
Pierre-Yves Longaretti and Nicole Borderies

171 **Doublet Craters and the Tidal Disruption of Binary Asteroids**
H. J. Melosh and J. A. Stansberry

180 **Laboratory Simulations of Large Scale Fragmentation Events**
Kevin R. Housen, Robert M. Schmidt, and Keith A. Holsapple

191 **Derivation of Midinfrared (5–25 μm) Optical Constants of Some Silicates and Palagonite**
T. Roush, J. Pollack, and J. Orenberg

209 **Laboratory Reflectance Measurements of Analogues to "Dirty" Ice Surfaces on Atmosphereless Solar System Bodies**
John R. Stephens and Bo Å. S. Gustafson

218 **Asteroid 4 Vesta: Simultaneous Visible and Ultraviolet IUE Observations**
M. C. Festou, S. A. Stern, and G. P. Tozzi

232 **Convection and Lithospheric Strength in Dione, an Icy Satellite of Saturn**
Olivier Forni, Angioletta Coradini, and Costanzo Federico

Notes

246 **A Search for Distant Satellites of Pluto**
S. Alan Stern, Robert A. Fesen, Edwin S. Barker, Joel Wm. Parker, and Laurence M. Trafton

250 **Does Debris from the Formation of Other Planetary Systems Impact Earth?**
Thomas G. Brophy

Book Reviews

255 *Origin of the Earth*. Edited by H. W. Newsom and J. H. Jones
George W. Wetherill

256 *Physics and Chemistry of Comets*. Edited by Walter F. Huebner
Michael R. Combi

Number 2, December 1991

257 Acknowledgment: A Summary of the Year's Activities at *Icarus*
Joseph A. Burns

259 In Memoriam: Oleg V. Dobrovolsky (1914–1989)
M. Ya. Marov and S. I. Ibadov

260 Kuiper Prize Lecture: Some Problems in the Formation of the Planets
V. S. Safronov

272 Angular Momentum Transfer in Low Velocity Oblique Impacts: Implications for Asteroids
Masahisa Yanagisawa, Janusz Eluszkiewicz, and Thomas J. Ahrens

283 Impact Experiments 3: Catastrophic Fragmentation of Aggregate Targets and Relation to Asteroids
Eileen V. Ryan, William K. Hartmann, and Donald R. Davis

299 The Lifetime of Binary Asteroids vs Gravitational Encounters and Collisions
B. Chauvineau, F. Mignard, and P. Farinella

311 The Natural Thermoluminescence of Meteorites. II. Meteorite Orbits and Orbital Evolution
P. H. Benoit, D. W. G. Sears, and S. W. S. McKeever

326 An Experimental Study of the Sublimation of Water Ice and the Release of Trapped Gases
R. L. Hudson and B. Donn

333 Sublimation and Reformation of Icy Grains in the Primitive Solar Nebula
Jonathan I. Lunine, Steffi Engel, Bashar Rizk, and Mihaly Horanyi

345 Solid C≡N Bearing Material on Outer Solar System Bodies
Dale P. Cruikshank, L. J. Allamandola, William K. Hartmann, D. J. Tholen, R. H. Brown, C. N. Matthews, and J. F. Bell

354 $CH_4/NH_3/H_2O$ Spark Tholin: Chemical Analysis and Interaction with Jovian Aqueous Clouds
Gene D. McDonald, Bishun N. Khare, W. Reid Thompson, and Carl Sagan

368 Brine Volcanism and the Interior Structures of Asteroids and Icy Satellites
Jeffrey S. Kargel

391 The Shape of Tethys
P. C. Thomas and S. F. Dermott

399 Tidal Origin of the Laplace Resonance and the Resurfacing of Ganymede
Renu Malhotra

413 The Mass of Neptune
David A. Pierce

420 Nonradial Oscillations of Saturn
Mark S. Marley

436 Nonlinear Satellite Wakes in Planetary Rings. I. Phase-Space Kinematics
Glen R. Stewart

451 **Structure and Particle Properties of Saturn's E Ring**
Mark R. Showalter, Jeffrey N. Cuzzi, and Stephen M. Larson

474 **Multifrequency Radio Observations of Saturn at Ring Inclination Angles between 5 and 26 Degrees**
Imke de Pater and John R. Dickel

493 **Venera-15 and -16 Middle Atmosphere Profiles from Radio Occultations: Polar and Near-Polar Atmosphere of Venus**
O. I. Yakovlev, S. S. Matyugov, and V. N. Gubenko

511 **Comet Levy (1990c): Groundbased Photometric Results**
David G. Schleicher, Robert L. Millis, David J. Osip, and Peter V. Birch

Erratum

524 **Volume 87, Number 2 (1990): Renu Malhotra, "Capture Probabilities for Secondary Resonances," pp. 249–264**

526 *Author Index for Volume 94*

527 *Cumulative Subject Index for Volumes 89–94*

ICARUS

International Journal of Solar System Studies

INFORMATION FOR AUTHORS

ICARUS is devoted to the publication of original contributions in the field of solar system studies. Manuscripts reporting the results of new research—observational, experimental, or theoretical—concerning the astronomy, geology, meteorology, physics, chemistry, biology, and other scientific aspects of our solar system or extrasolar systems are welcome. The journal generally does not publish papers devoted **exclusively** to the Sun, the Earth, celestial mechanics, meteoritics, or astrophysics. The language of publication is English. In special cases, with the Editor's approval, short abstracts of papers can also appear in French, German, or Russian. All papers are reviewed, generally by two independent referees. Authors will usually be asked to respond to criticisms and suggestions by the referees prior to publication; at the Editor's discretion, reviewers may be consulted about resubmitted manuscripts. Authors are invited to submit a list of no more than five potential reviewers; the Editor may use this to guide his selection of referees. If authors so request in their cover letters, manuscripts will be handled anonymously during the refereeing process.

Manuscripts are accepted for review with the understanding that the same work has not been published, that it is not under consideration for publication elsewhere, and that its submission for publication has been approved by all of the authors and by the institution where the work was carried out; further, that any person cited as a source of personal communications has approved such citation. Written authorization may be required at the Editor's discretion. For the benefit of the reviewers, three (3) copies of all crucial references cited in the manuscript as *submitted* or *in press* must accompany the paper. Articles and any other material published in ICARUS represent the opinions of the authors and should not be construed to reflect the opinions of the Editor or the Publisher.

Authors submitting a manuscript do so on the understanding that if it is accepted for publication, copyright in the article, including the right to reproduce the article in all forms and media, shall be assigned exclusively to the Publisher. The Publisher will not refuse any reasonable request by the author for permission to reproduce any of his or her contributions to the journal.

There are no page charges. However, authors will be charged for color reproduction or foldout pages; the publisher will provide an estimate of these costs on request. Fifty **reprints** of each paper will be furnished gratis to the author and additional reprints may be purchased.

Manuscripts. *Four copies* of the manuscript, including figures, tables, etc., should be submitted to:

Editorial Office, **Icarus**
Space Sciences Building
Cornell University
Ithaca, New York 14853-6801

Telephone: 607-255-4875
Fax: 607-255-9002
Electronic mail:
CUSPIF::ICARUS on SPAN
or
icarus@astrosun.tn.cornell.edu on internet

Authors should retain the original typescript. At least one set of figures should be suitable for camera-ready reproduction. All manuscripts must be typewritten with wide margins and *double-spaced throughout*, including references and footnotes. Number each page of the manuscript. Include on the first page the title of the paper and the name(s) and affiliation(s) of the author(s), including mailing address(es) and telephone number(s) [or telex number(s) or electronic mail address(es)]. At the bottom of the first page note the number of manuscript pages, figures, and tables; also list up to five key words (topics), taken from the journal's index, that classify the subject of the paper. On the second page indicate a proposed running head of not more than 60 characters, and the name and address to which editorial correspondence and proofs should be directed. The third page should contain a brief abstract, and the text should begin on the following page. After the main text, give Appendixes, Acknowledgments, references, tables, figure captions, and figures, in that order. Places where figures and tables are to appear in the published paper should be marked in the margins of the manuscript.

Please write with attention to organization, style, and especially brevity. Present results logically, with order dictated by the needs of the reader. Take special care in composing the title and abstract, since these will be the most frequently read sections of the paper. In the title, specific words are preferable to general ones. The abstract should summarize the conclusions of the research, including quantitative results where appropriate, rather than merely stating the problem.

Whenever possible, quotients in mathematical expressions should employ the solidus (/) rather than being displayed in built-up form. However, for units, exponential notation is preferred (e.g., erg cm^{-2} sec^{-1}, not erg/cm^2 sec). Most authors will recall the difference between "i.e." and "e.g.," will note that such nouns as "data" are plural and "mare" singular, and will take care to insert a zero before decimal fractions lying between $+1$ and -1.

Guidelines for Submission of "Notes." Papers on especially topical subjects will be given unusually rapid handling if they satisfy the following limitations on length:

(i) Manuscripts should be typed double-spaced and should be no longer than nine pages, including a very brief abstract of one or two sentences.

(ii) The sum of figures and tables should be less than, or equal to, two.

We expect that ICARUS will publish "Notes" within four months of submission, if no revision is required. We will try to complete refereeing and editorial handling in less than one month. In order to speed publication, proofs of "Notes" will be proofread only at Academic Press.

Tables and Figures. When described in the body of the text, a table should be referred to as Table X, and a figure as Fig. Y (use the abbreviation everywhere except at the beginning of a sentence).

Tables are to be numbered consecutively with Roman numerals in order of their citation in the text. Each table should be typed, *double-spaced,* on a separate sheet with due regard to the proportions of the printed page. All tables should bear appropriate headings. Unusually elaborate tables should be prepared to allow them to be reproduced in the journal directly without typesetting.

Figures. At the time of submission of the manuscript, one original of each figure is to be submitted in such form as to permit photographic reproduction without redrawing: Line glossies should be carefully drafted, no larger than 22 × 30 cm. Original drawings, laser prints, or standard glossy photographic reproductions are acceptable. *Authors should design figures so that they will fit one or two columns of print. Care should be taken to assure that computer-drawn figures use the journal's space efficiently.* Lettering on drawings should be of professional quality or generated by *high-resolution* computer graphics and should be large enough (10–12 points) to take a reduction of 50–60%. Drawings should be made with black India ink on tracing linen, smooth-surface white paper, or Bristol board. Alternatively, *high-quality* computer graphics may be acceptable. Graph paper, if used, should be ruled in blue. *Each figure should be identified with the author's name and figure number.* All figures, whether line drawings or halftones, should be numbered consecutively in Arabic numerals, in order of their citation in the text. Figure captions should be typewritten on a separate sheet, following the text. Color plates and foldouts are published at the author's expense.

Literature Citations. *Careful compliance with the instructions for the preparation of the list of references is required;* manuscripts with incomplete references (or missing abstracts) may be returned to the author for correction before being considered for publication.

Literature citations in the text should be in one of the following forms: Goody and Yung 1989 (for two authors); Farinella *et al.* 1990 (for three or more authors); Allison 1990, p. 198 (for reference to a specific page). To distinguish two or more works by the same author(s) in the same year, use suffixes a, b, etc., following the year (e.g., Ojakangas and Stevenson 1989a, 1989b).

Literature citations in the bibliography should be *listed alphabetically* according to the surname of the (first) author. Journal references should contain the *names and initials of all authors, the year, the title of the article, and standard abbreviation of the journal, the volume number, and the first and last page numbers.* Titles of journals and books should be in italics, volume numbers in boldface. (In a typed manuscript, indicate italics by single underlining and boldface by wavy underlining.) Below are shown examples of the proper reference forms for a book, a book chapter, and a journal article, respectively.

CHAMBERLAIN, J. C., AND D. M. HUNTEN 1987. *Theory of Planetary Atmospheres, An Introduction to Their Physics and Chemistry,* 2nd ed. Academic Press, San Diego.

SCHOLL, H., CH. FROESCHLÉ, H. KINOSHITA, M. YOSHIKAWA, AND J. G. WILLIAMS 1989. Secular resonances. In *Asteroids II* (R. P. Binzel, T. Gehrels, and M. S. Matthews, Eds.), pp. 845–861. Univ. of Arizona Press, Tucson.

SPENCER, J. R. 1990. A rough-surface thermophysical model for airless planets. *Icarus* **83,** 27–38.

Proofs will be sent to authors. When submitting a manuscript, the author should include a list of the symbols employed, identified typographically, not mathematically. This list will not be printed, but will help to avoid costly author's corrections in proof. Authors will be charged for excessive alterations in proof.

Personal Computer Disks

Manuscripts may be submitted to ICARUS on personal computer disks after the manuscript has been accepted and after all revisions have been incorporated onto the disk. Please supply the file as a straight ASCII file with generic codes specified by the publisher. Label the disk with the type of computer used, the type of software and the version number, and the disk format. All tabular and mathematical material will be typeset conventionally. Art must be prepared as camera-ready copy; see the section on Figures earlier in this Information for Authors.

A hard copy printout of the manuscript that exactly matches the disk file must be supplied. Academic Press will not accept disks without accompanying printouts of all files on the disk. File names must clearly indicate the content of each file. The manuscript will be edited according to the style of the journal, and the proofs must be read carefully by the author. Disks that are not translatable or economical to process will not be used. The publisher reserves the right not to use the disk.

For further information on preparing the disk for typesetting conversion and a list of generic codes, please contact the publisher (Associate Director, Journal Division, Academic Press, 1250 Sixth Avenue, San Diego, California 92101; Telephone: 619 699-6415; Fax: 619 699-6800).